Unit 10
Ecology

Chapter 40: Population Ecology and the Distribution of Organisms

- **Ecology** is the scientific study of the interactions between organisms and the environment
- The **biosphere** is the sum of all the planet's ecosystems (atmosphere, hydrosphere, lithosphere)
- A **landscape** (or seascape) is a mosaic of connected ecosystems
- An **ecosystem** is the community of organisms in an area and the physical factors with which they interact
- A **community** is a group of populations of different species in an area
- A **population** is a group of individuals of the same species living in an area

- **Biotic** factors are the other organisms that make up the living component of the environment
- **Abiotic** factors are the nonliving chemical and physical attributes of the environment
- **Weather** = day to day variations in temperature, precipitation, sunlight, and wind conditions
- **Climate** = long-term prevailing (average) weather conditions in an area
  - Latitudinal variations in climate
    - Sunlight strikes the tropics most directly

- Climate is affected by
  - Seasonal variations in light and temperature
    - Caused by the tilt of Earth's axis
  - Large bodies of water
    - Moderate climate of nearby land due to water's high specific heat capacity
  - Mountains
    - Influence air flow over land
      - Moisture on windward side
      - Dry air on leeward side (deserts)

Terrestrial Biomes

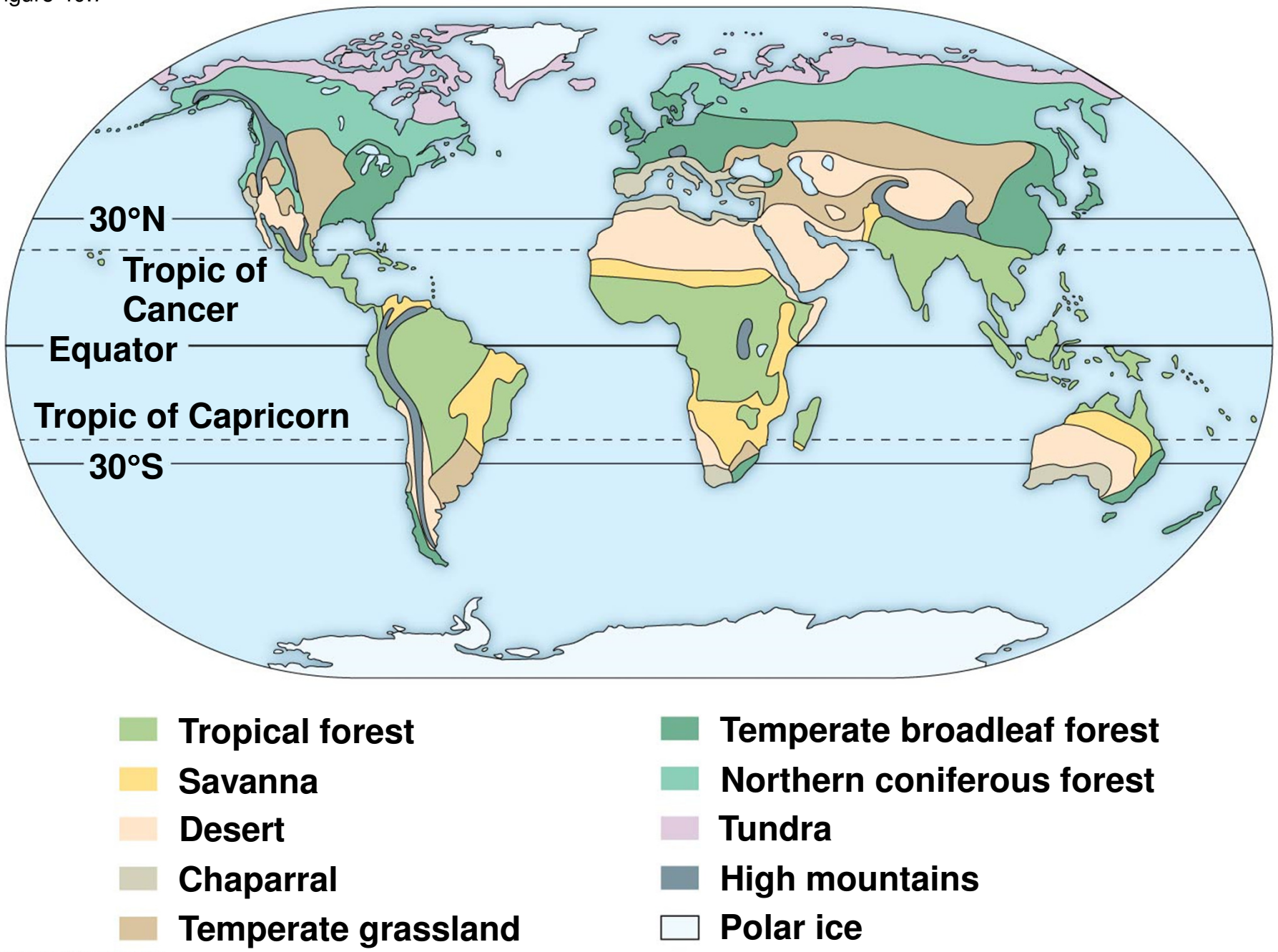
- **Biomes** are major life zones characterized by
  - Distribution
  - Precipitation
  - Temperature
  - Organisms
    - Plants and animals depend on temp, precip, soil
- Climate is very important in determining why terrestrial biomes are found in certain areas

Biome	Soil	Climate	Plants and Animals
	•Thin •Nutrient poor	•Hot •Very wet (>95in/yr)	•Home to more species than others combined •Canopy and understory with large leaves •Active animals
	•Some nutrients •Frequent fires	•Hot •Dry season and wet season	•Tall grasses; isolated trees •Migrating, grazing, burrowing animals
	•Thin •Porous •Nutrient poor	•Hot days; cold nights •Very dry (<10in/yr)	•Cacti •Nocturnal animals

Biome	Soil	Climate	Plants and Animals
	•Fertile •Deep and nutrient rich	•Warm/hot summers; cold winters •10-60 in precip/year (mostly snow)	•Lush grasses •Grazing and burrowing animals
	•Fertile •Nutrient rich and well developed	•Warm summers; cold winters •30-80 in precip/year	•Deciduous and coniferous trees •Hibernating and migrating animals

Biome	Soil	Climate	Plants and Animals
	•Acidic	•Short summers; long, cold winters •15-20 in precip/year (sticks around)	•Tall redwoods; conifers •Animals with extra insulation
	•Permafrost •Thin and perpetually frozen	•Long, cold, dark winters with strong winds •Low precip (<5 in/yr but sticks around)	•Mosses •Animals with small extremities

Figure 40.7


30°N
Tropic of Cancer
Equator
Tropic of Capricorn
30°S
Tropical forest
Savanna
Desert
Chaparral
Temperate grassland
Temperate broadleaf forest
Northern coniferous forest
Tundra
High mountains
Polar ice

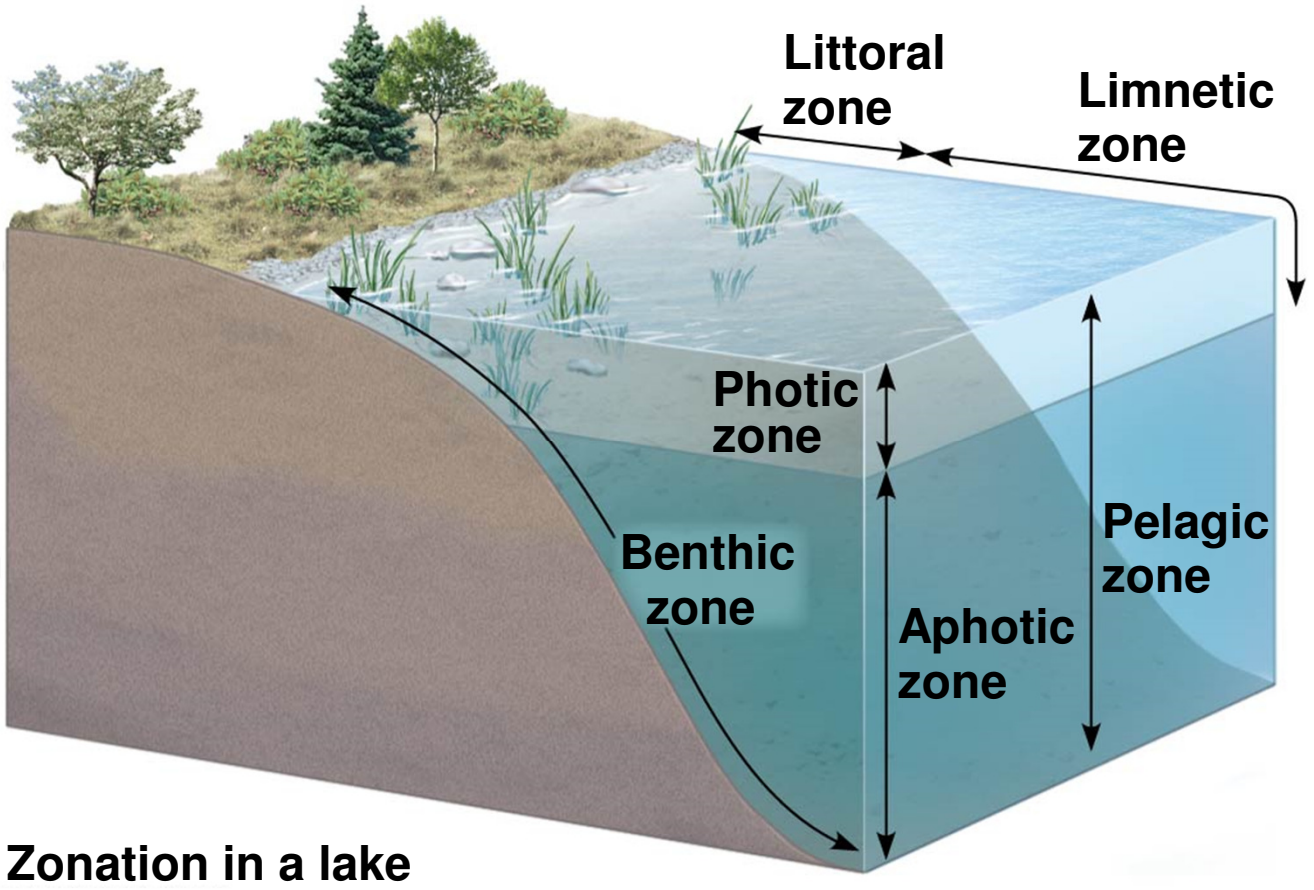
Aquatic Biomes

- **Wetlands** are inundated by water at least sometimes and support plants adapted to water-saturated soil
- An **estuary** is a transition area between river and sea
- **Oligotrophic lakes** are nutrient-poor and generally oxygen-rich
- **Eutrophic lakes** are nutrient-rich and often depleted of oxygen
- Rooted and floating aquatic plants live in the shallow and well-lighted **littoral zone** close to shore
- Water is too deep in the **limnetic zone** to support rooted aquatic plants

- **Intertidal zones** are periodically submerged and exposed by the tides
  - Organisms here must be adapted to variations in temperature and salinity and by the forces of waves
  - Oxygen and nutrient levels are high
- **Coral reefs** are formed from the calcium carbonate skeletons of corals (cnidarians)
  - Very diverse habitat

- Many aquatic biomes are stratified into zones or layers defined by light penetration, temperature, and depth
- The upper **photic zone** has sufficient light for photosynthesis
- The lower **aphotic zone** receives little light
- The photic and aphotic zones make up the **pelagic zone**
- The organic and inorganic sediment at the bottom of all aquatic zones is called the **benthic zone**
  - The communities of organisms in the benthic zone are collectively called the **benthos**

Figure 40.11



Zonation in a lake

- In oceans and most lakes, a temperature boundary called the **thermocline** separates the warm upper layer from the cold deeper water
- Communities in aquatic biomes vary with depth, light penetration, distance from shore, and position in the pelagic or benthic zone
  - Most organisms occur in the relatively shallow photic zone
  - The aphotic zone in oceans is extensive but harbors little life

Distribution of Organisms

- Biotic factors that affect the distribution of organisms may include
  - Predation
  - Herbivory
  - Mutualism
    - Presence or absence of pollinators
  - Parasitism and pathogens
  - Food resources
    - Competition

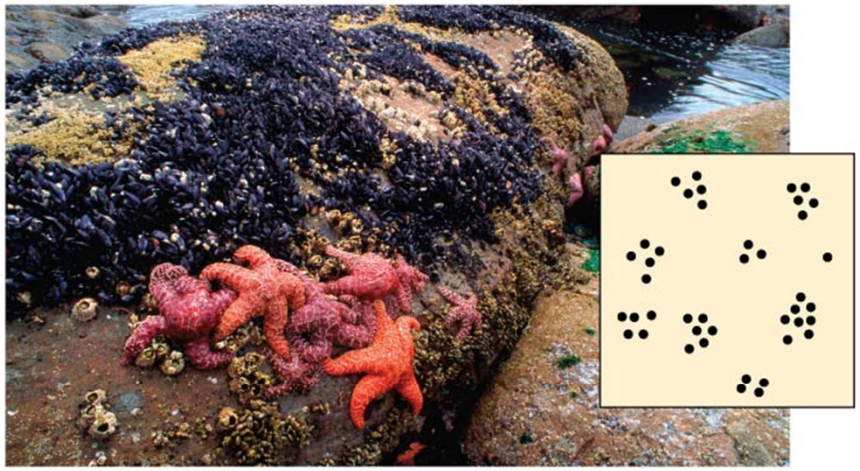
- Abiotic factors affecting the distribution of organisms include
  - Temperature
  - Water and oxygen
  - Salinity
  - Sunlight
  - Rocks and soil

Density and Dispersion

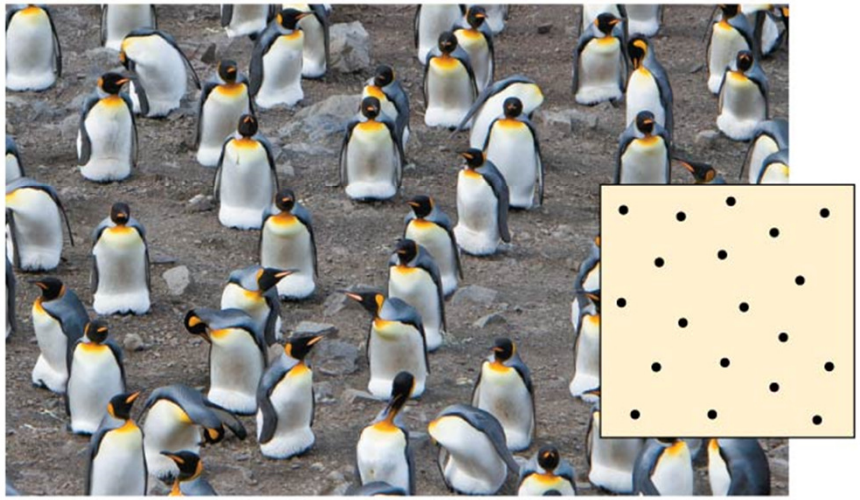
- **Density** is the number of individuals per unit area or volume
  - Additions occur through birth and **immigration**
    - Influx of new individuals from other areas
  - Removal of individuals occurs through death and **emigration**
    - Movement of individuals out of a population
- **Dispersion** is the pattern of spacing among individuals within the boundaries of the population

- The most common pattern of dispersion is ***clumped***
  - May be influenced by resource availability (food or water) and behavior (like predation or defense)
- A ***uniform*** dispersion is one in which individuals are evenly distributed
  - May result from **territoriality** (defense of a bounded space against other individuals)
- In a ***random*** dispersion, the position of each individual is independent of other individuals
  - Occurs in the absence of strong attractions or repulsions (homogenous)

Figure 40.15



(a) Clumped

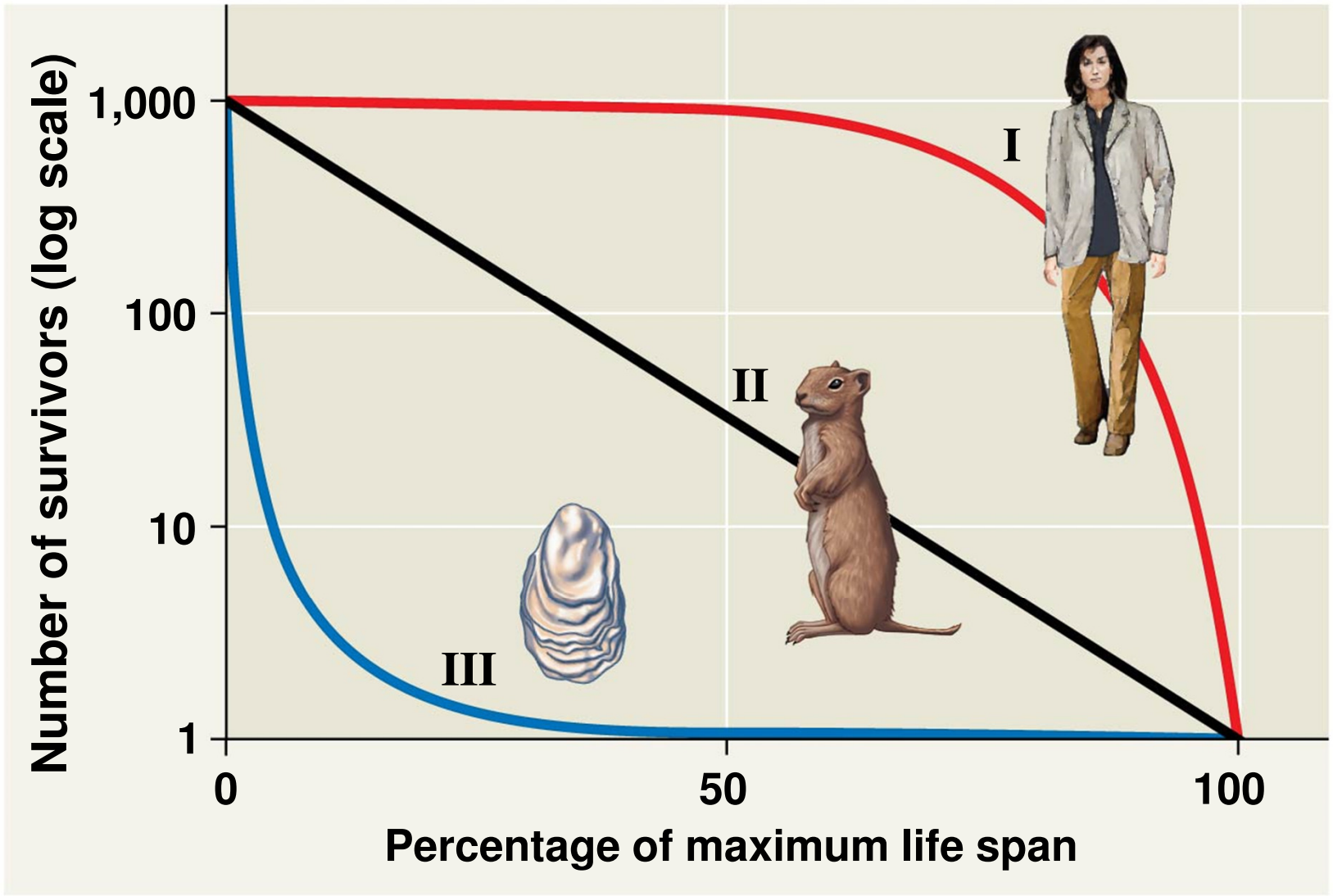


(b) Uniform

(c) Random

- Survivorship curves can be classified into three general types
  - Type I: low death rates during early and middle life and an increase in death rates among older age groups
    - Large mammals, including humans
  - Type II: a constant death rate over the organism's life span
    - Rodents, invertebrates, lizards, annual plants
  - Type III: high death rates for the young and a lower death rate for survivors
    - Organisms that produce large numbers of offspring with little/no parent care (long-lived plants, fish, marine invertebrates)
- Many species are intermediate to these curves

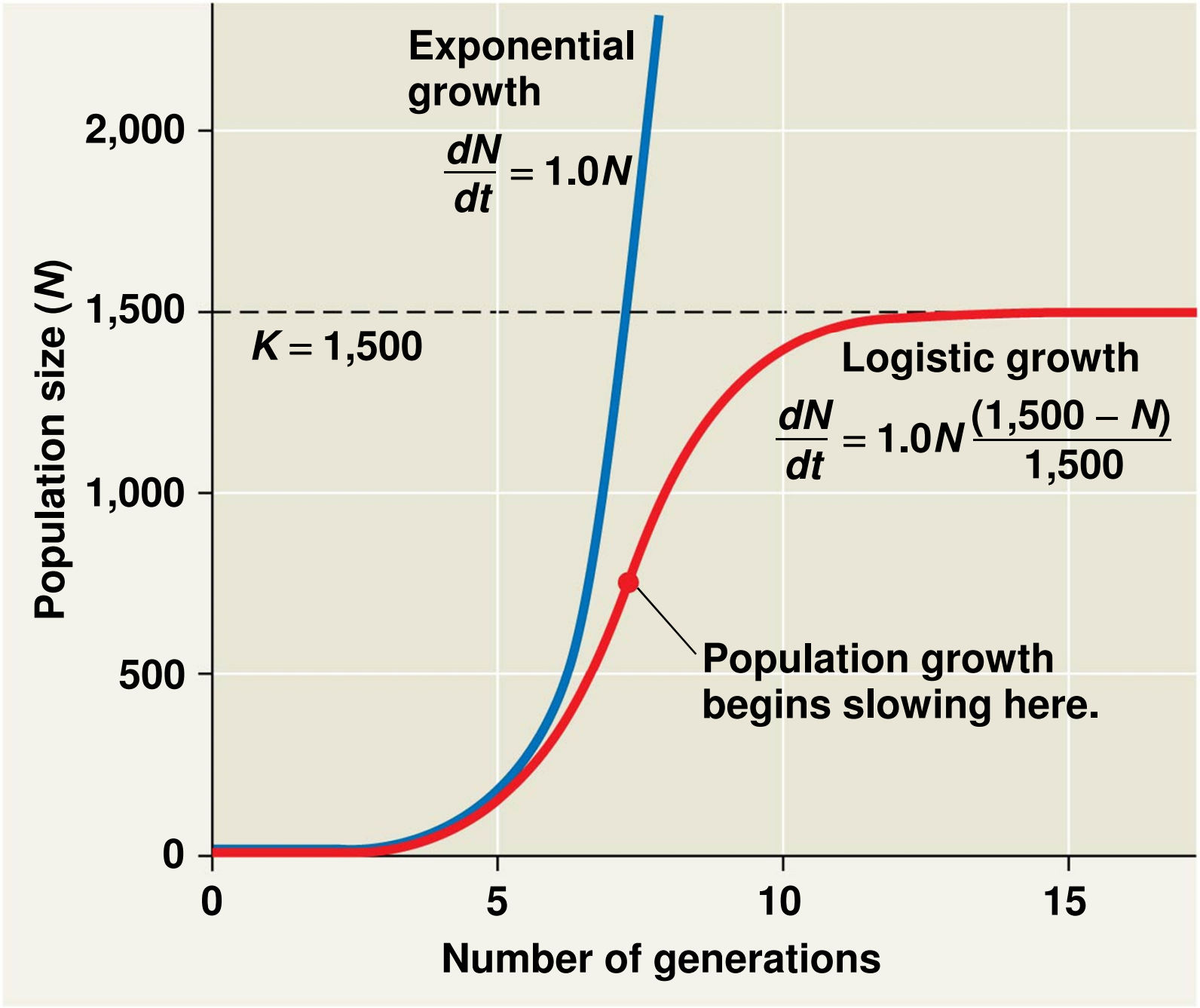
Figure 40.16


Number of survivors (log scale)
1,000
100
10
1
0
50
100
Percentage of maximum life span
I
II
III

Exponential vs Logistic Growth

- **Exponential population growth** is population increase under idealized conditions
  - Results in a J-shaped curve
  - Characterizes populations in new environments or rebounding populations (more resources)
  - Note: Cannot be sustained for long in any population (will eventually crash at that rate), as it assumes resources are unlimited
- **Carrying capacity** (*K*) is the maximum population size the environment can support
  - Varies with the abundance of limiting resources
- In the **logistic population growth** model, the per capita rate of increase declines as carrying capacity is reached
  - Produces an S-shaped curve

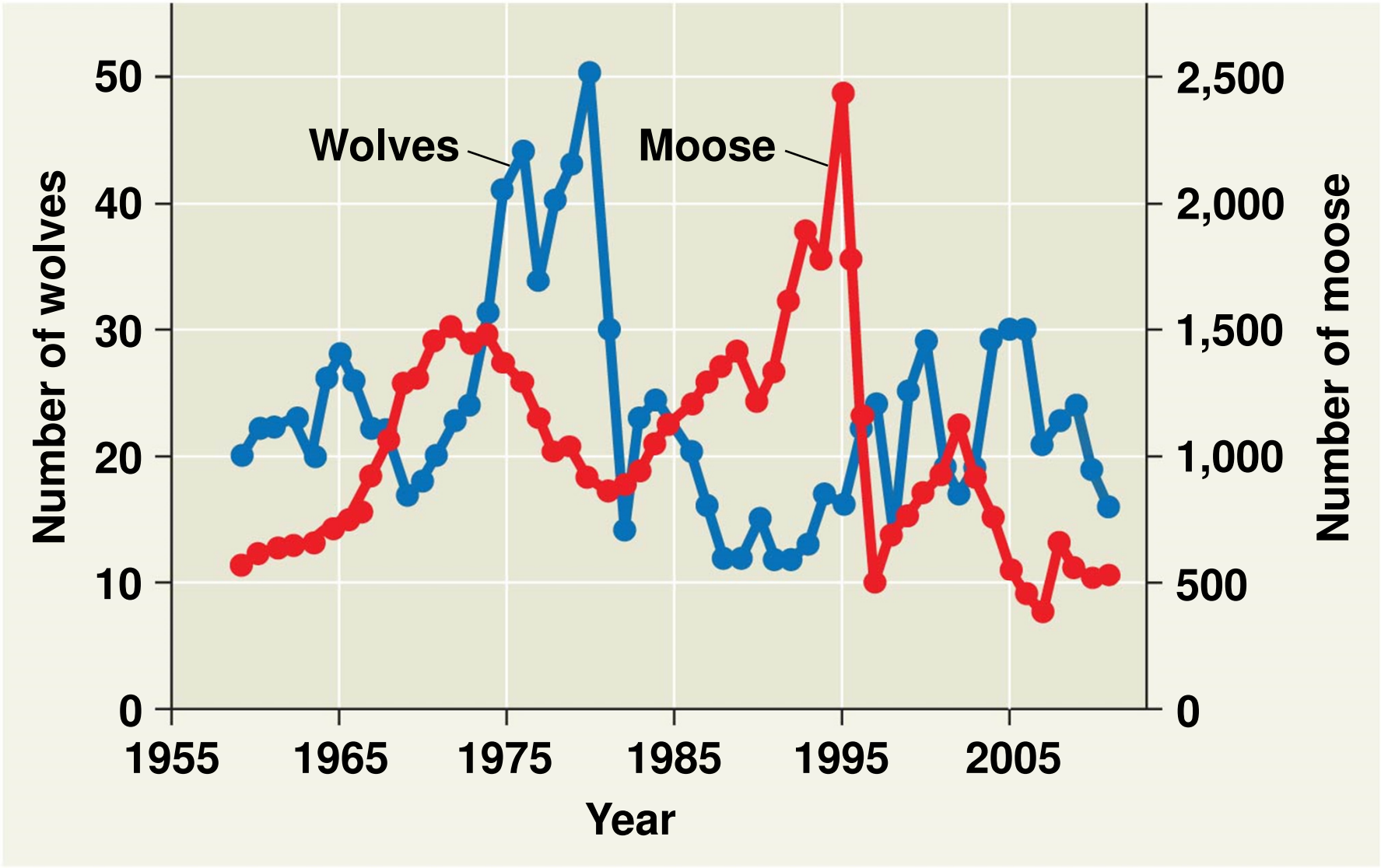
Figure 40.19


Exponential growth
$\frac{dN}{dt} = 1.0N$
2,000
1,500
1,000
500
0
$K = 1{,}500$
Logistic growth
$\frac{dN}{dt} = 1.0N\frac{(1{,}500 - N)}{1{,}500}$
Population growth begins slowing here.
Population size (N)
0
5
10
15
Number of generations

- ***K*-selection** selects for life history traits that are sensitive to population density
  - Density-dependent selection
  - Old and established
  - Influenced by carrying capacity
- ***r*-selection** selects for life history traits that maximize reproduction
  - Density-independent selection
  - New and empty
  - Grows at faster (exponential) rate

- Density-dependent birth and death rates are affected by many factors, such as
  - Competition for resources
  - Territoriality
  - Disease
  - Predation
  - Pollution
  - Intrinsic factors (like hormonal changes)
- Density-independent birth and death rates do not change with population density but are affected by natural disasters

Figure 40.24


Wolves
Moose
Number of wolves
Number of moose
Year
0
10
20
30
40
50
0
500
1,000
1,500
2,000
2,500
1955
1965
1975
1985
1995
2005

Unit 10
Ecology
Chapter 41: Species Interactions

Competition

- **Interspecific competition** occurs when species compete for a resource that limits their growth or survival (–/– interaction)
- The **competitive exclusion principle** states that two species competing for the same limiting resources cannot coexist in the same place
  - Best suited organism outcompetes the other
  - Must have different niches
- An **ecological niche** is the specific set of biotic and abiotic resources used by an organism
  - Organism's ecological role
  - Habitat = "address"; niche = "profession"

Predation

- **Predation** refers to an interaction in which one species, the predator, kills and eats the other, the prey (+/- interaction)
- Some feeding adaptations of predators are
  - Acute senses
  - Claws, teeth, stingers, and poison
  - Speed or camouflage
- Prey display various defensive adaptations
  - Behavioral defenses include hiding, fleeing, forming herds or schools, and active self-defense

- Prey also have morphological and physiological defense adaptations
  - **Cryptic coloration**, or camouflage
  - Mechanical or chemical defenses like quills, foul odors, or toxins
    - **Aposematic coloration** = Bright colors warn of toxin
  - Mimicry
    - **Batesian mimicry** = a palatable or harmless species mimics an unpalatable or harmful model
    - **Müllerian mimicry** = two or more unpalatable species resemble each other

Figure 41.5

(a) Cryptic coloration

► Canyon tree frog

(b) Aposematic coloration

► Poison dart frog

(c) Batesian mimicry: A harmless species mimics a harmful one.

◄ Nonvenomous hawkmoth larva

▼ Venomous green parrot snake

(d) Müllerian mimicry: Two unpalatable species mimic each other.

◄ Cuckoo bee

▼ Yellow jacket

Herbivory

- **Herbivory** refers to an interaction in which an herbivore eats parts of a plant or alga (+/- interaction)
- In addition to behavioral adaptations, some herbivores may have chemical sensors or specialized teeth or digestive systems
- Plant defenses include chemical toxins and protective structures

Symbiosis

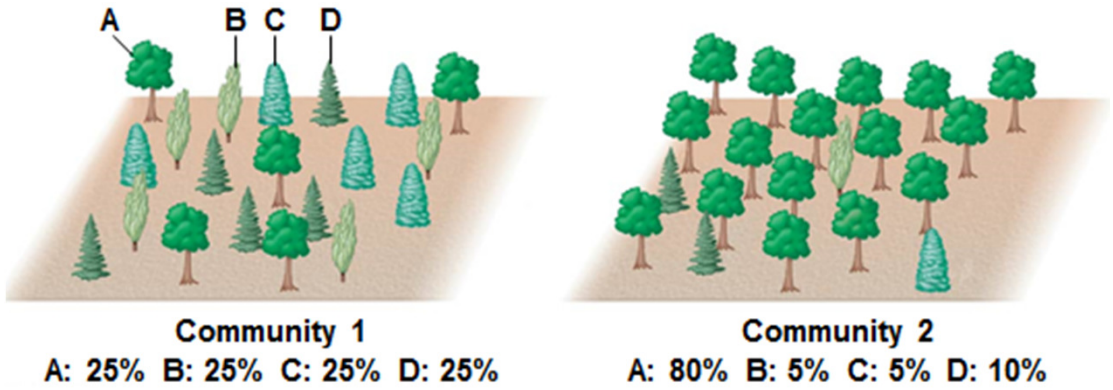
- **Symbiosis** is a relationship where two or more species live in direct and intimate contact with one another
  - **Parasitism =** one organism derives nourishment from another organism (**host**), which is harmed in the process (+/- interaction)
    - Ex: Tapeworms, ticks
  - **Mutualism** = both species benefit (+/+ interaction)
    - Ex: Clownfish and sea anemone
  - **Commensalism** = one species benefits and the other is neither harmed nor helped (+/0 interaction)
    - Ex: “Hitchhiking” species

Facilitation

- **Facilitation** is an interaction in which one species has positive effects on another species without direct and intimate contact
  - (+/+ or 0/+)
  - Makes environment more suitable
  - Particularly common in plants ecology
    - Ex: The black rush makes the soil more hospitable for other plant species

Species Diversity

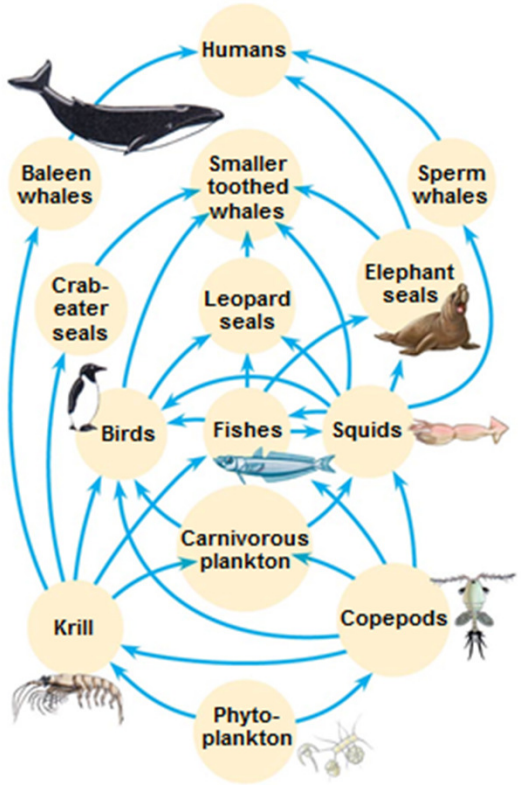
- **Species diversity** of a community is the variety of organisms that make up the community
- It has two components:
  - **Species richness** is the number of different species in the community
  - **Relative abundance** is the proportion each species represents of all individuals in the community
- Communities with higher diversity are more stable!



- **Dominant species** are those that are most abundant or have the highest biomass
- **Keystone species** exert strong control on a community by their ecological roles, or niches
  - They are not necessarily abundant, but their removal results in collapse of the ecosystem
  - Ex: Sea stars
- **Ecosystem engineers** (or "foundation species") cause physical changes in the environment that affect community structure
  - Impact could be positive or negative
  - Ex: Beaver dams

Trophic Structure (Feeding Relationships)

- A **food web** traces flow of energy from
  - Autotrophs (primary producers) to
  - Herbivores (primary consumers) to
  - Carnivores (secondary, tertiary, quaternary consumers)
  - And eventually to detritivores
- Note: Inefficient! (Only 10% of energy is passed to next trophic level)



Ecological Succession

- **Ecological succession** is the sequence of community and ecosystem changes after a disturbance
  - **Primary succession** occurs where no soil exists when succession begins
    - New volcanic island
    - Rubble left by retreating glacier
  - **Secondary succession** begins in an area where soil remains after a disturbance
    - Fire

Unit 10
Ecology
Chapter 42: Ecosystems and Energy

- Energy flows through ecosystems
  - Energy enters most ecosystems as sunlight
  - Converted to chemical energy by autotrophs
  - Passed to heterotrophs in food
  - Dissipated as heat
- Matter cycles within ecosystems
  - Chemical elements, like carbon and nitrogen, are cycled among abiotic and biotic components of ecosystems
- Both energy and matter are transformed in ecosystems through photosynthesis and feeding relationships
  - But unlike matter, energy cannot be recycled!

- First law of thermodynamics
  - Energy cannot be created or destroyed, only transferred or transformed
- Second law of thermodynamics
  - Every exchange of energy increases the entropy of the universe
    - In an ecosystem, energy conversions are not completely efficient
      - Some energy is always lost as heat
    - Need continuous input of energy from the sun

- **Primary production** = amount of light energy converted to chemical energy by autotrophs during a given time period
  - **Gross primary production (GPP)** = total primary production
  - **Net primary production (NPP)** = GPP minus energy used by primary producers for "autotrophic respiration"
    - Only NPP is available to consumers!
- Tropical rain forests, estuaries, and coral reefs are most productive per unit area
- Marine ecosystems are relatively unproductive per unit area but contribute much to global net primary production because of their volume

- In marine and freshwater ecosystems, both light and nutrients control primary production
  - Nutrients like nitrogen and phosphorus are major limiting factors
- In terrestrial ecosystems, temperature and moisture affect primary production on a large scale
  - Primary production increases with moisture

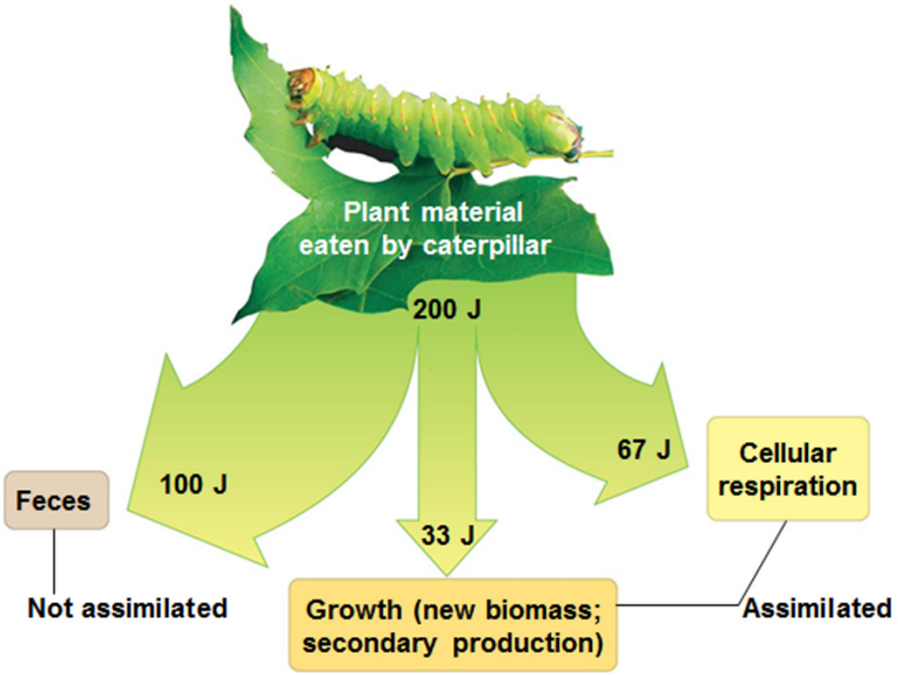
- **Secondary production** = amount of chemical energy in food converted to new biomass during a given period of time
- **Net secondary production** = energy stored in biomass
  - Only the chemical energy stored by herbivores as biomass is available as food to secondary consumers
    - Some energy is lost through waste or heat

- **Production efficiency** = fraction of energy stored in food that is not used for respiration

$$\text{Production efficiency} = \frac{\text{Net secondary production} \times 100\%}{\text{Assimilation of primary production}}$$

  - Birds and mammals have lower efficiencies because of the high cost of endothermy
  - Insects and microorganisms are much more efficient
- **Trophic efficiency** = percentage of production transferred from one trophic level to the next
  - Usually about 10%!
  - Limits # of trophic levels

Production efficiency = $\frac{\text{net secondary production x 100}}{\text{assimilation of primary production}}$



$\frac{33}{33 + 67}$ x 100 = 33%

What if….100 J eaten, 30 J used in respiration, 50 J lost in feces
Net secondary production = 100 – (30 +50) = 20 J
Production efficiency = 20 / (20 + 30) = 0.4 x 100 = 40%

Cycles

The Water Cycle

- Water moves by the processes of
  - Evaporation and transpiration
  - Condensation
  - Precipitation
  - Movement through surface and groundwater

The Carbon Cycle

- CO_2 is taken up by the process of photosynthesis
- Converted to glucose and passed through food webs
- CO_2 is released into the atmosphere through cellular respiration

The Nitrogen Cycle

- The main reservoir of nitrogen is the atmosphere (N_2)
- **Nitrogen fixation** by bacteria converts nitrogen gas to NH_4^+ or NO_3^- to be used by plants
- **Denitrification** converts NO_3^- back to N_2

The Phosphorus Cycle

- The largest reservoirs of phosphorus are sedimentary rocks
  - Weathering
  - No gas phase

Unit 10
Ecology

Chapter 43: Global Ecology and Conservation Biology

- **Bioremediation** is the use of organisms to detoxify ecosystems
- **Biological augmentation** uses organisms to add essential materials to a degraded ecosystem

- **Endangered species** = in danger of becoming extinct throughout all or a significant portion of its range
- **Threatened species** = likely to become endangered in the near future

- **Introduced species** = moved by humans from native locations to new geographic regions
  - Also called exotic or invasive species
  - Often disrupt new community